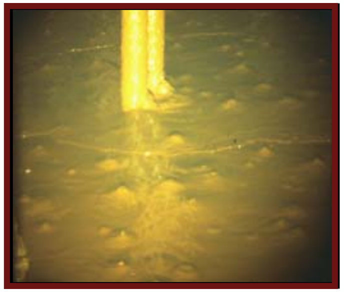
SRS savannah river site

SRNL SAVANNAH RIVER NATIONAL LABORATORY

We Put Science To Work

Overview of the Design Basis, Operating Experience, and the Application of Laboratory Data to Support the Transport and Mixing of Sludge Slurries in the Defense Waste Processing Facility



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Agenda

- Overview of operations: Defense Waste Processing Facility (DWPF)
- Savannah River National Laboratory (SRNL) characterization techniques
  - Chemical and physical characterization
  - Recent efforts
- Modeling efforts
- Identification of unresolved issues
- Conclusions

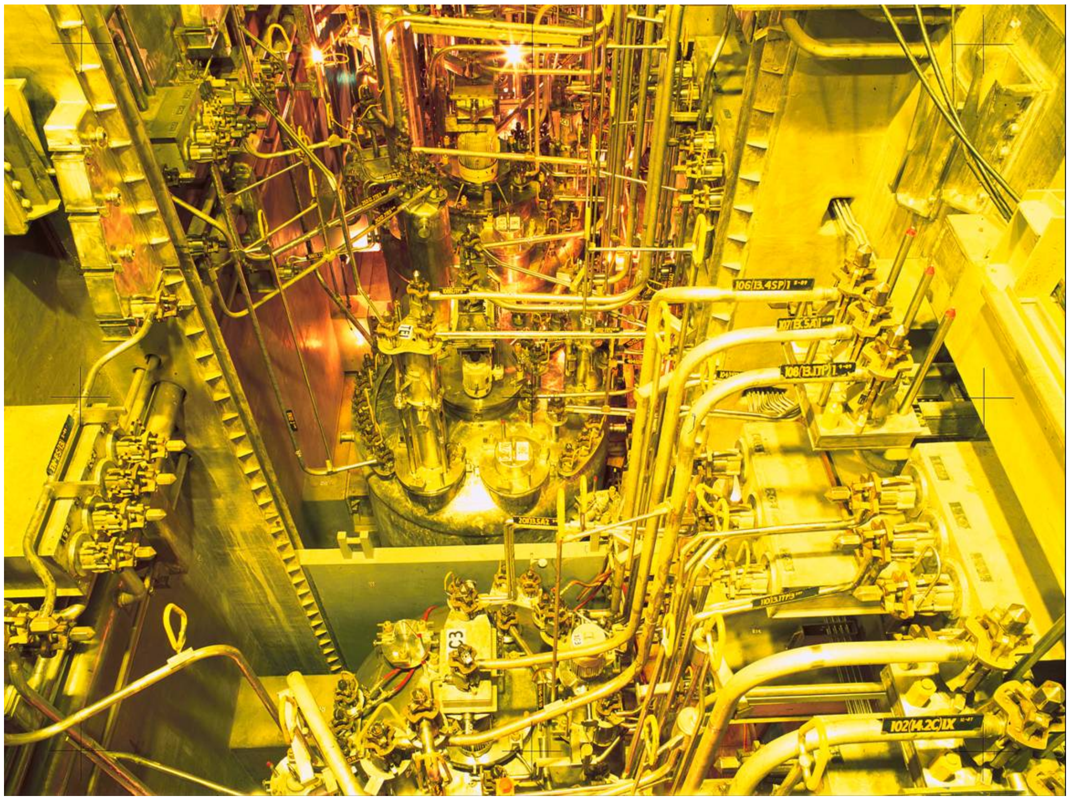
DWPF: Operations Overview

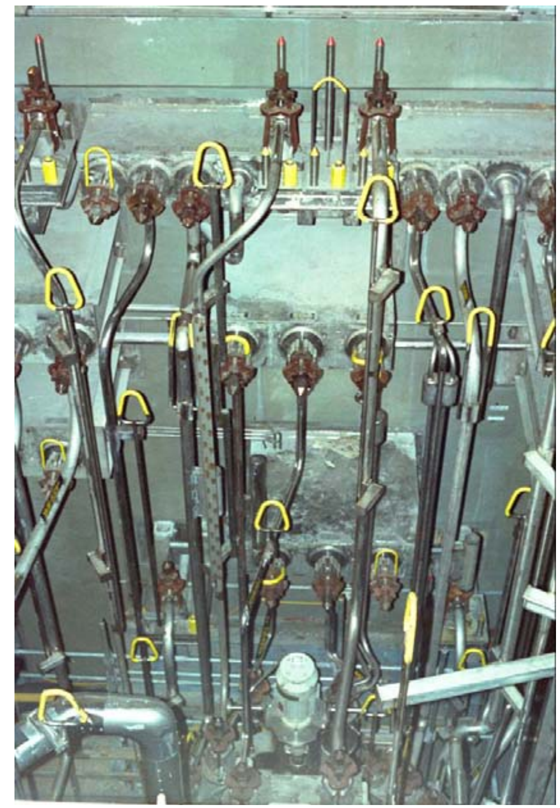
Design purpose is to process and vitrify high level waste for safe, permanent geological storage

- Receipt and chemical adjustment/concentration
- Frit addition
- Melter feed and canister pouring

DWPF: Transport Issues

Complex canyon configuration complicates transport issues



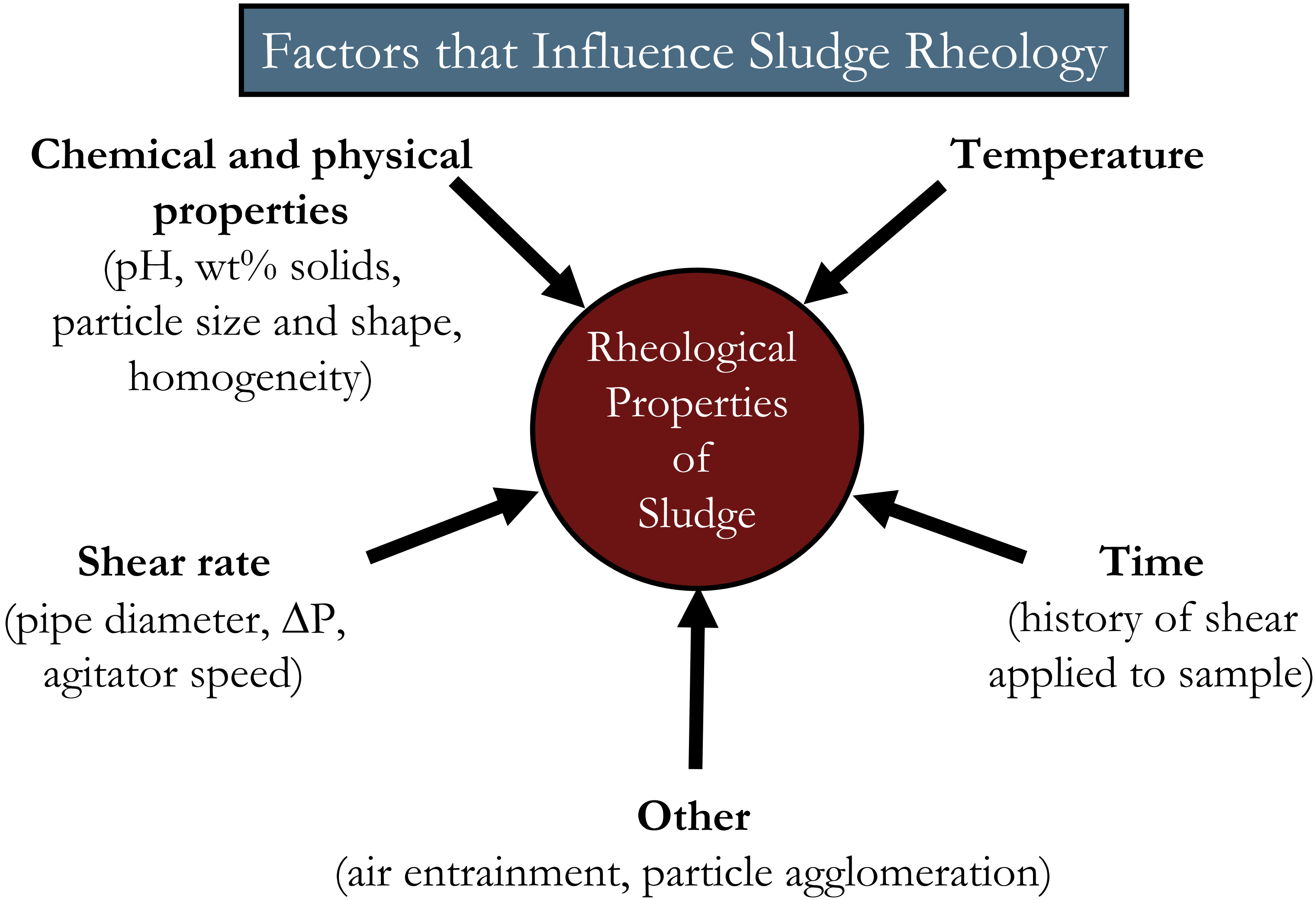


DWPF: Transport Issues

- Chemical and physical properties of sludge differ significantly among batches
  - HM sludge → high Aluminum
  - Purex sludge → high Iron

Sludge Batch	Problem Type	Problem Description
SB1a	Chemical	Inability to destroy nitrite
SB1b	Rheological	Sludge slurry exhibited tacky nature
SB2	Rheological	Sludge exhibited excessive air entrainment/foaminess
SB3	Chemical	Greater quantities of off-gassing as a result of higher anion concentrations
SB4	Chemical/Rheological	Greater quantities of off-gassing as a result of higher anion concentrations; melter feed pump issues

DWPF: Transport Issues



Tools Available

- No ability to evaluate rheology while in canyon

- Issues which may impact DWPF processing are typically identified during sludge batch **qualification**

- SRNL research and DWPF modeling efforts

GOAL: To avoid future process interruptions due to transport issues by having the ability to mitigate problems quickly and effectively, and to improve overall processing at DWPF.

DWPF Qualification

Prior to processing sludge at DWPF, it is well-characterized through SRNL radioactive and nonradioactive testing

SRNL

Qualification activities with **radioactive sample**

Sludge characterization
Sludge washing or concentration, as necessary
Demonstration of the Sludge Receipt and Adjustment Tank (SRAT) cycle
Adjusts feed rheology and removes components problematic to melting
Demonstration of the Slurry Mix Evaporator (SME) cycle
Adds frit and concentrates the slurry to the target solids
Fabrication of glass for Product Consistency Test (PCT) durability testing

Qualification activities with **simulant**

Flowsheet testing to define DWPF SRAT/SME parameters
Glass variability study to verify the acceptability of the durability models

SRNL: Analytical Methods

Density

- Plastic pipette tips are sealed with hot glue
- Volume calibrated using DI water (V_i)
- Sample placed into sealed tip using slurry pipette
- Mass of sample recorded (M_i)
- Density calculated: $\rho_i = \frac{M_i}{V_i}$
- Three to four measurements are made per sample

SRNL: Analytical Methods

Solids analysis

- Alumina crucibles used to obtain dried mass
  - Crucibles dried at ~115 °C, cooled and weighed
  - Sample transferred using slurry pipette and weighed (M_{total})
  - Sample dried at 115 °C until mass differential is less than 0.010 g (M_{dried})
- Sample placed into furnace to obtain calcined mass ($M_{calcined}$)
  - Furnace ramped to 1100 °C at 5 °C/min
  - Held at 1100 °C for two hours
  - When T<500 °C, crucible removed from furnace and air cooled prior to weighing
- Total/Calcine slurry and soluble solids in the supernate fractions are calculated:

$$f_{total\_solids} = f_{ts} = \frac{M_{slurry,dried}}{M_{slurry,total}} \qquad f_{calcined\_solids} = f_{cs} = \frac{M_{slurry,calcined}}{M_{slurry,total}} \qquad f_{supernate\_solids} = f_{ds} = \frac{M_{supernate,dried}}{M_{supernate,total}}$$

- Insoluble solids fraction calculated using conservation of mass:

$$f_{insoluble\_solids} = f_{is} = \frac{f_{ts} - f_{ds}}{1 - f_{ds}}$$

SRNL: Analytical Methods

EXAMPLE: Reduce sludge mass via removal of aluminum

Reduction in number of canisters produced

	Tank 51 Before Al Dissolution (SC3) Products		Tank 51 After Al Dissolution (SC4) Products		
Physical Property	SRAT	SME	SRAT	SME	Units
Wt% Total Solids in Slurry	**21.3**	**49.6**	**22.6**	**48.4**	**%**
Wt% Soluble Solids In Supernate	**11.5**	**14.7**	**14.0**	**17.2**	**%**
Wt% Insoluble Solids in Slurry	**11.1**	**40.8**	**10.0**	**37.6**	**%**
Density of Slurry	**1.22**	**1.44**	**1.17**	**1.46**	**g/ml**
Density of Supernate	**1.09**	**1.12**	**1.10**	**1.13**	**g/ml**

- Total solids analysis are similar for both SRAT/SME products; differences apparent in soluble and insoluble contributions

SRNL: Rheology

Rheological measurements

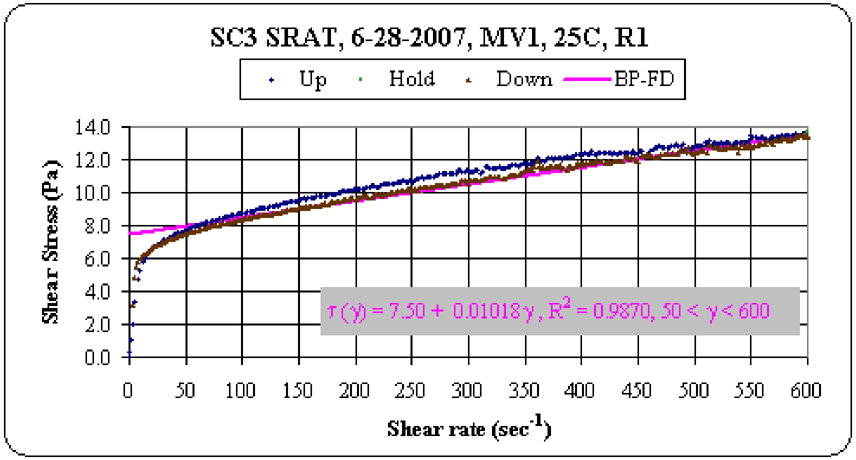
- Haake RV20/30 rotoviscometer is utilized
  - Haake RV20/30 is functional-verified as operational using a NIST traceable oil standard to within +/- 10% of the standard at 25 °C whenever sample measurements are made
- Sample placed into transfer cup and then placed into RV20/30 cup
  - Assists in removing entrained air bubbles
- Forward and backward rate sweeps performed on all materials
- Flow curve measurements are performed at 25 °C
- Newtonian shear rate data is fitted with Bingham Plastic rheological model to determine Bingham Plastic yield stress and plastic viscosity

$$\tau = \tau_0 + \eta_{pl}\dot{\gamma}$$

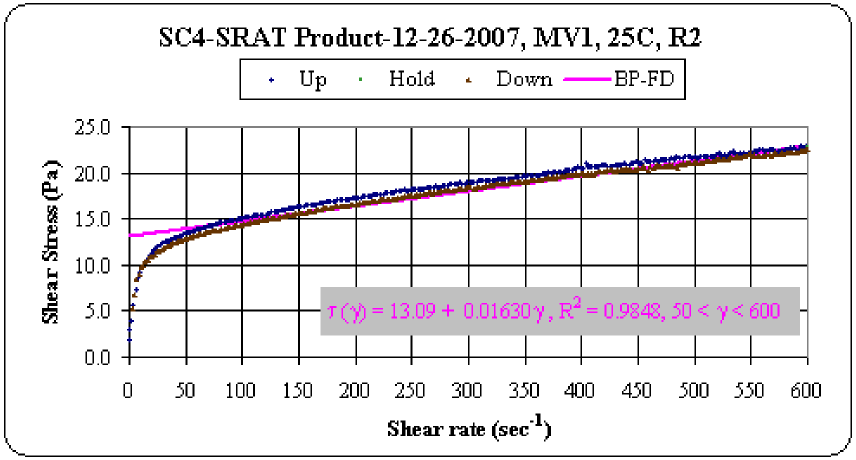
- Currently, simulants are not suited to represent rheological behavior of radioactive waste

SRNL: Rheology

SRAT Product without LTAD



SRAT Product with LTAD

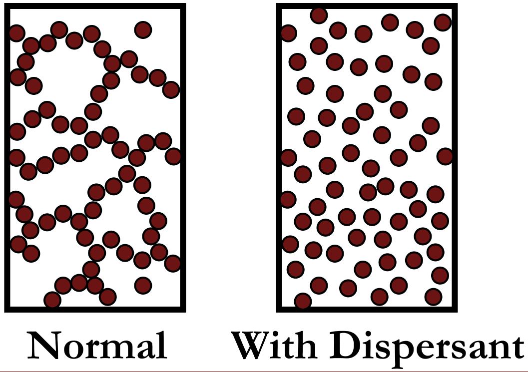


DWPF Design Basis in red

	Tank 51 Before Al Dissolution (SC3) Products		Tank 51 After Al Dissolution (SC4) Products		
Physical Property	SRAT	SME	SRAT	SME	Units
Bingham Plastic Yield Stress	7.2 (1.5-5)	10.9 (2.5-15)	13.3	21.6	Pa
Bingham Plastic Viscosity	10.2 (5-12)	19.8 (10-40)	16.5	29.2	cP

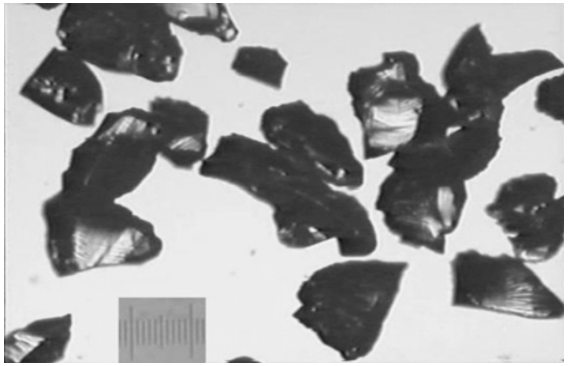
SRNL Work: Rheological Modifiers

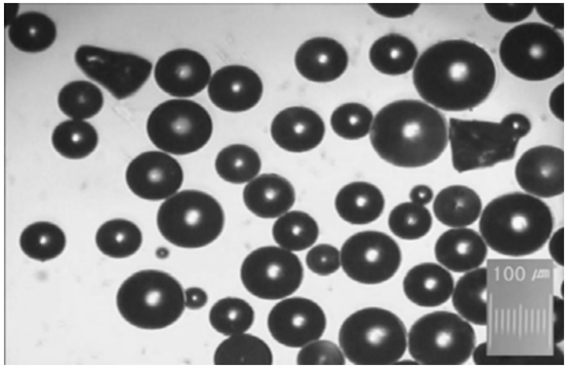
- Lower yield stress and consistency via prevention of particle agglomeration
  - Electrostatic
  - Steric
- Ethylene glycol and polyacrylate based dispersants studied (IIT)
  - Significant reduction in yield stress and moderate reduction of consistency during simulant testing
  - Mechanism based on steric break-down of gel-like structure
- Inherent difficulties
  - Effectiveness highly dependent upon pH
  - Impacts to DWPF unknown



SRNL Work: Frit Morphology

- Transport issues due to high solids loading
- Frit passed through flame and quenched with water
  - 90% morphology alteration rate
  - Nominal size distribution unchanged
- Overall reduction in both yield stress and consistency
  - Higher loadings
  - Improved melt rate via reduction of water content
- Potential negative impacts
  - Settling behavior
  - Glass/waste oxide interaction

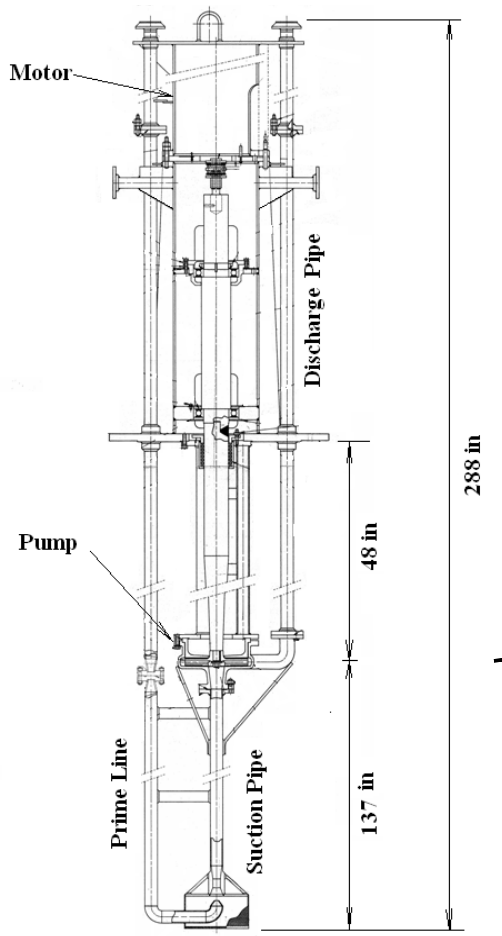




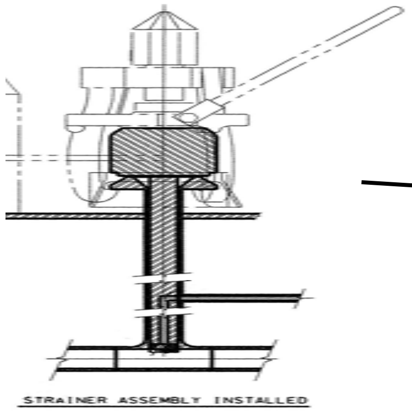
Modeling

Slurry mixing complicated by geometry of tanks

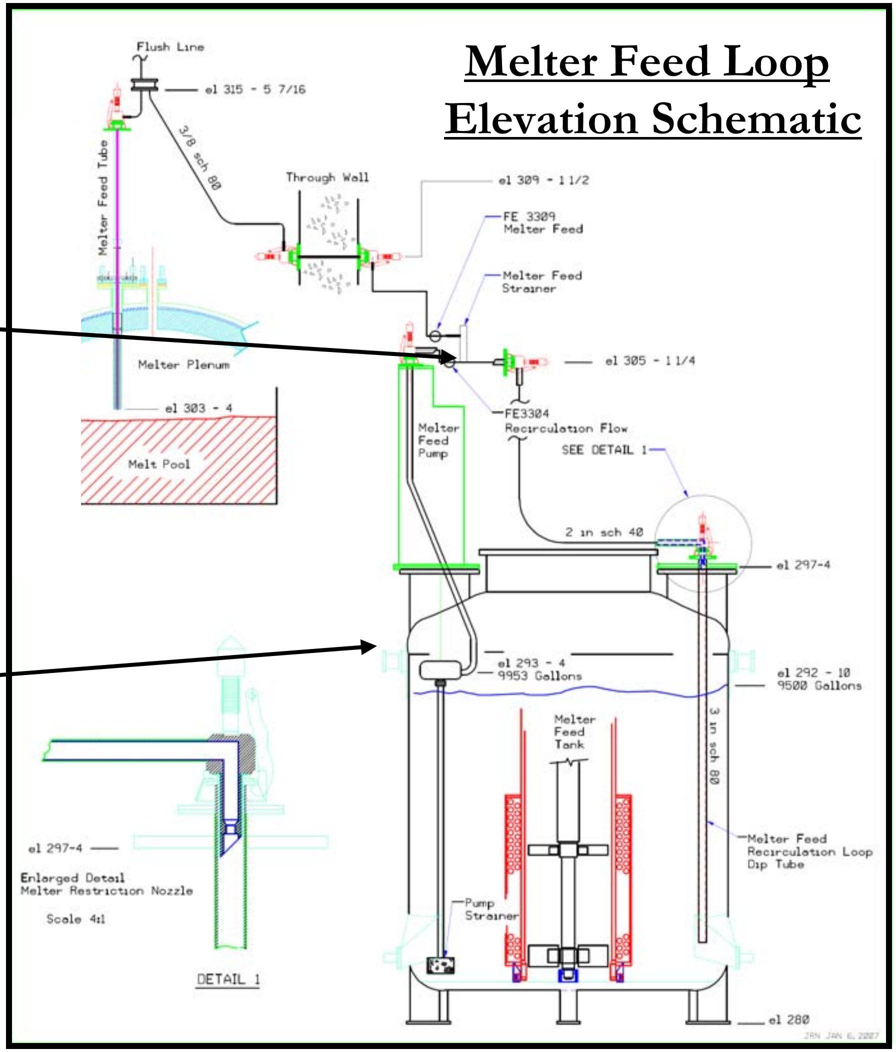
Modeling



Motor
Discharge Pipe
Pump
Prime Line
Suction Pipe
288 in
48 in
137 in



STRAINER ASSEMBLY INSTALLED



Melter Feed Loop
Elevation Schematic
Flush Line
el 315 - 5 7/16
3/8 sch 80
Melter Feed Tube
Through Wall
el 309 - 1 1/2
FE 3309
Melter Feed
Melter Feed
Strainer
el 305 - 1 1/4
Melter Plenum
el 303 - 4
Melt Pool
Melter
Feed
Pump
FE3304
Recirculation Flow
SEE DETAIL 1
2 in sch 40
el 297-4
el 293 - 4
9953 Gallons
el 292 - 10
9500 Gallons
Melter
Feed
Tank
3 in sch 80
Melter Feed
Recirculation Loop
Dip Tube
Pump
Strainer
el 297-4
Enlarged Detail
Melter Restriction Nozzle
Scale 4:1
DETAIL 1
el 280

Modeling

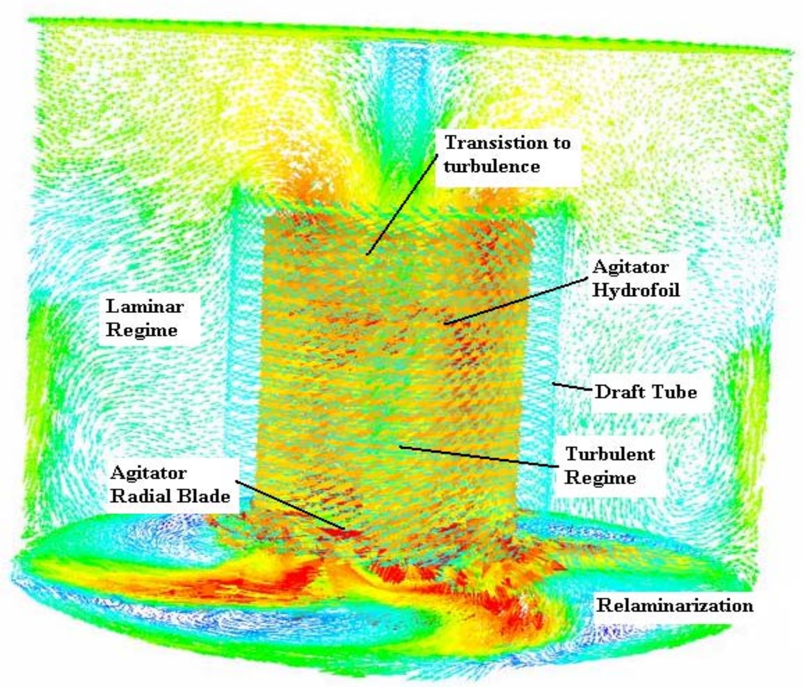
Melter Feed Tank (MFT) mixing process is being evaluated* by flow models built with Fluent Software

***This work is being performed by John Neuville and Professor Jamil Kahn from the University of South Carolina.**

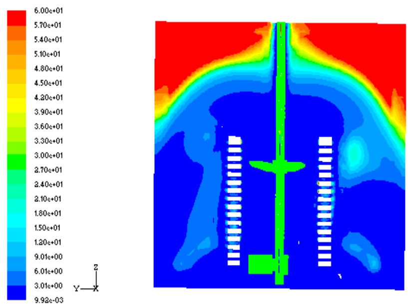
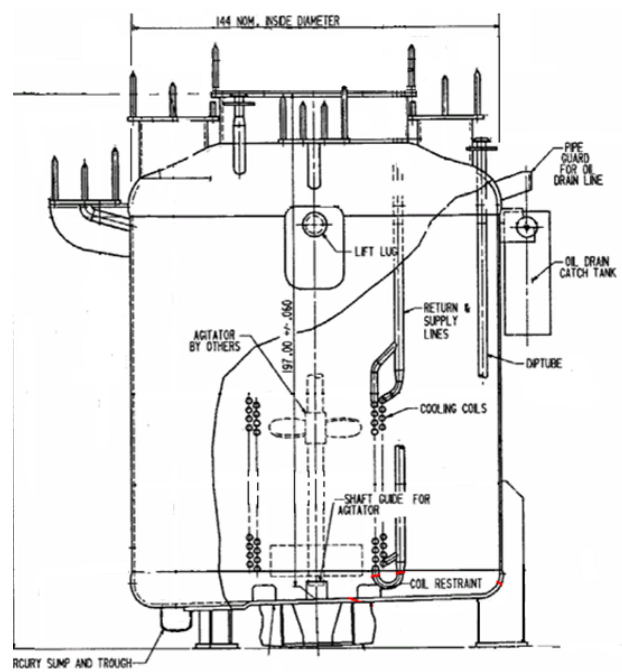
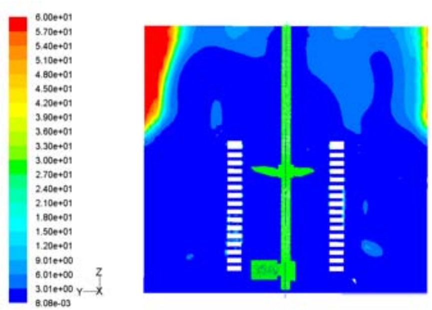
- Tank modeled has a helical cooling coil in the center of the tank, and a centrally located agitator that has two impellers; an axial blade is positioned above a radial blade located at the bottom of the tank.

- A mixture in a stirred tank that exhibits a Yield Stress behavior can create various regions in the tank where the flow field is stagnant, laminar, or turbulent.

- Historically tank mixing performance has been evaluated by developing small scale models. The data collected by these models is then scaled-up by the use of dimensional analysis and similarity principals.



Modeling

<table>
<tr><th colspan="2">CFD Scale Model Results- Stagnation Regions are Shown in Red</th></tr>
<tr><td>Scale Model Result 40 Gallon Tank
Herschel Bulkley; 5.0 Pa, 1.057 Pa*sec,
n = 0.4133, N = 250 rpm</td><td>DWPF Melter Feed Tank
9500 Gallon Tank</td></tr>
<tr><td></td><td rowspan="3"></td></tr>
<tr><td>Scale Model Result 40 Gallon Tank
Herschel Bulkley; 5.0 Pa, 1.057 Pa*sec,
n = 0.4133, N = 350 rpm</td></tr>
<tr><td></td></tr>
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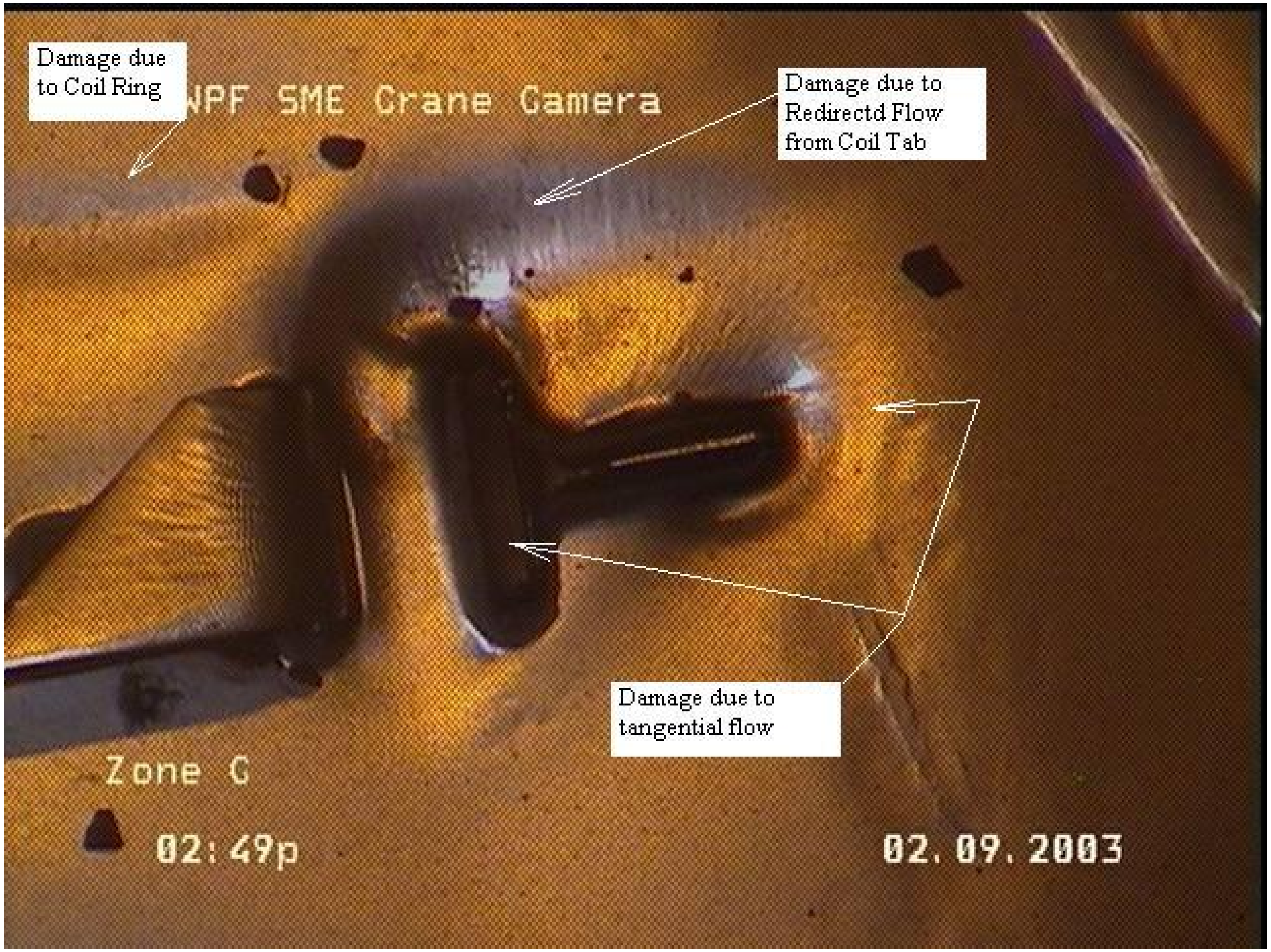
Modeling

Tank Erosion to Coil Guides



Identification of Data Gaps

- Limited data on radioactive samples
  - Effort to create rheology database
  - Development of new rheological tests

- Need for simulant more representative of physical behavior of real waste

- Constitutive relationship describing slurry flow behavior

Conclusions

- Transport issues inherent in DWPF process are critical to operability of facility

- Tools to help mitigate rheological issues available
  - SRNL characterization abilities
  - Supplemental SRNL research
  - Modeling efforts

- Limited database
  - Appropriate constitutive relationships
  - Data on radioactive samples, simulants

Acknowledgements

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Supplemental Slides

SRNL Capabilities

- Sample Prep
- Density
- Solids analysis
  - Total solids in slurry
  - Soluble solids in the supernate
  - Insoluble solids in slurry
  - Calcine solids in slurry
- Rheology
  - Flow curves
- SRNL ongoing efforts

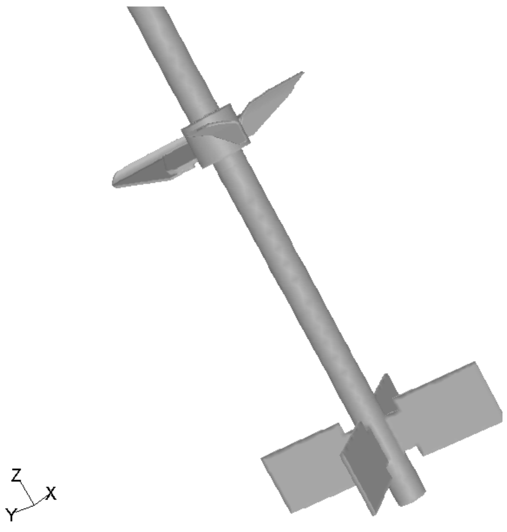
Low Temperature Aluminum Dissolution (LTAD) Example

SRNL: Analytical Methods

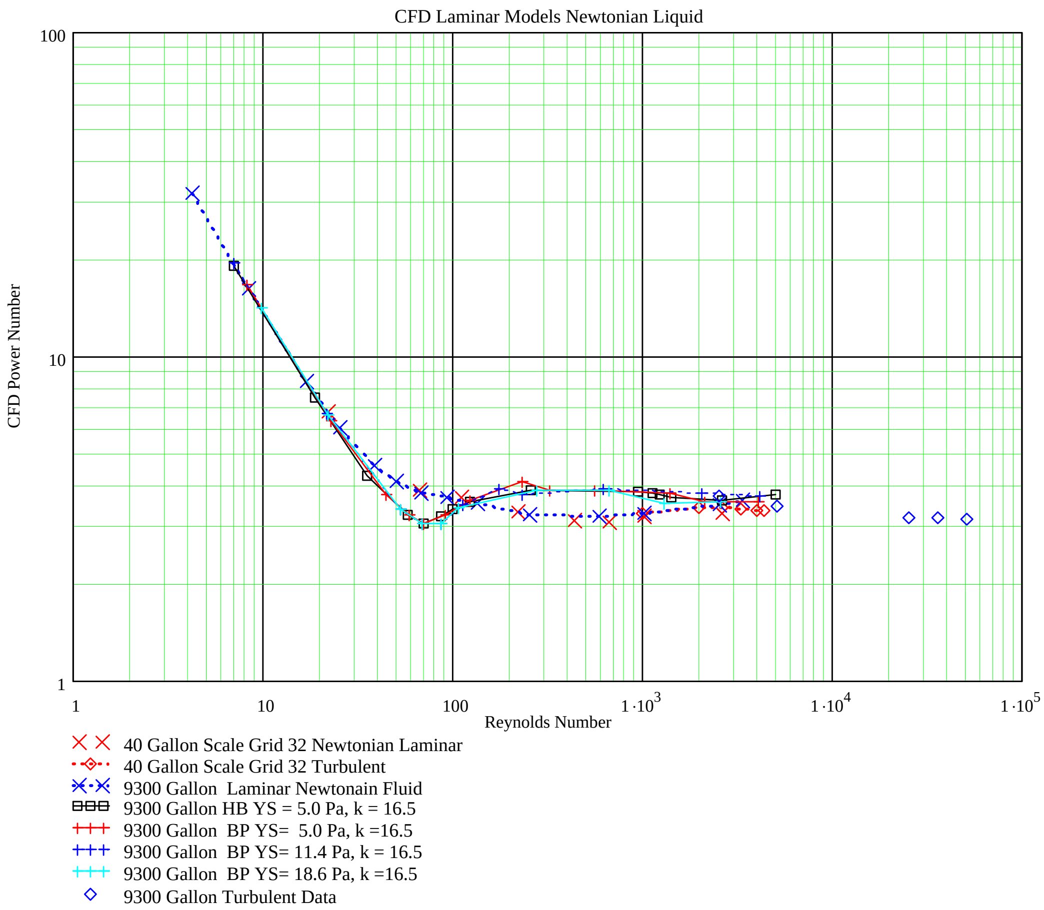
- Sample homogenized via shaking bottle. Rapid shaking can cause air entrainment.
- Sub samples are either transferred using slurry pipette or poured
- Sample reuse typically does not occur
- Supernate sample typically obtained by filtering a homogenized sample through a 0.45 micron filter

Modeling

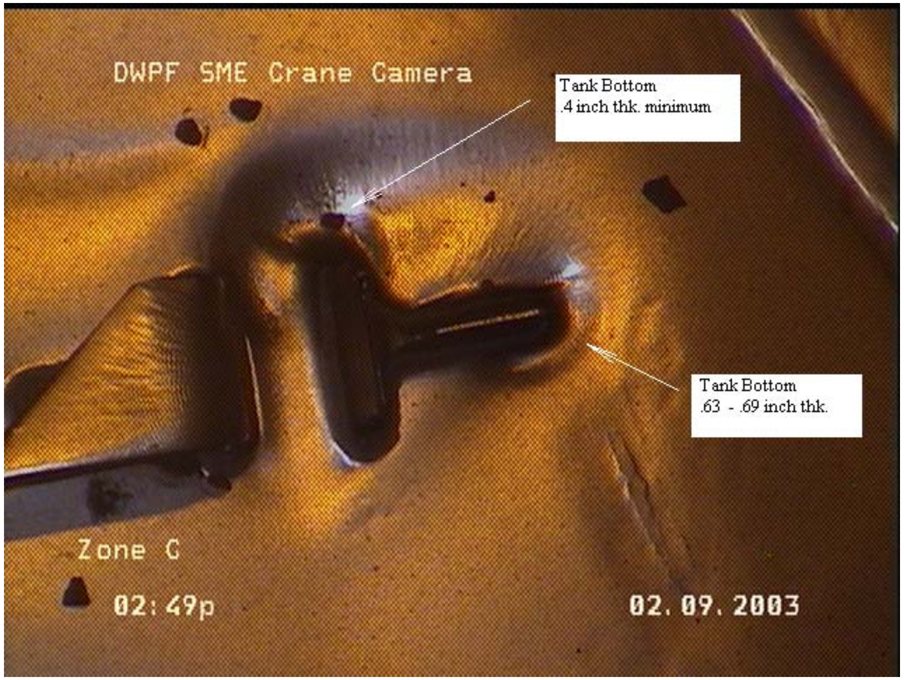
MFT Full Scale CFD Mixing Model

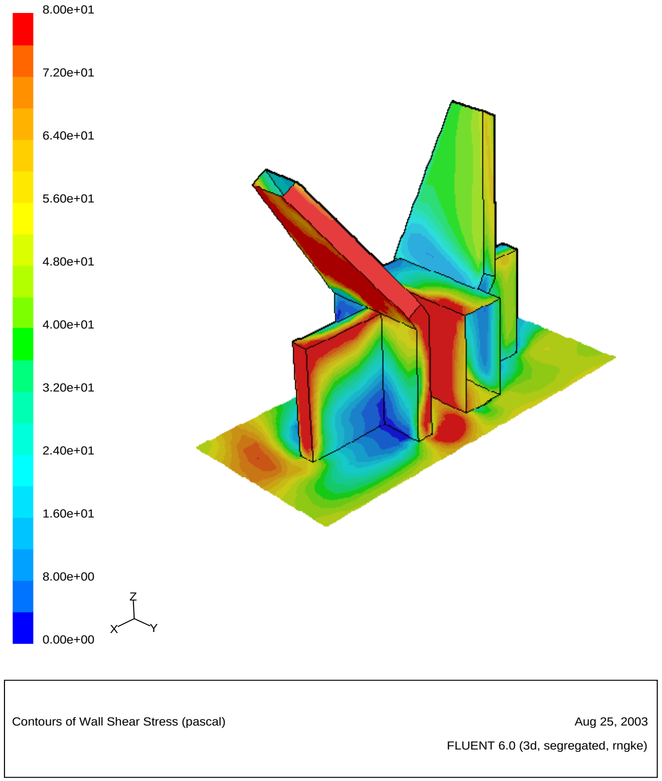


Otto-Metzner Laminar Curve
"Np = 136.8/Re"
Proportionality Constant for
Power Curves k =16.5



Modeling

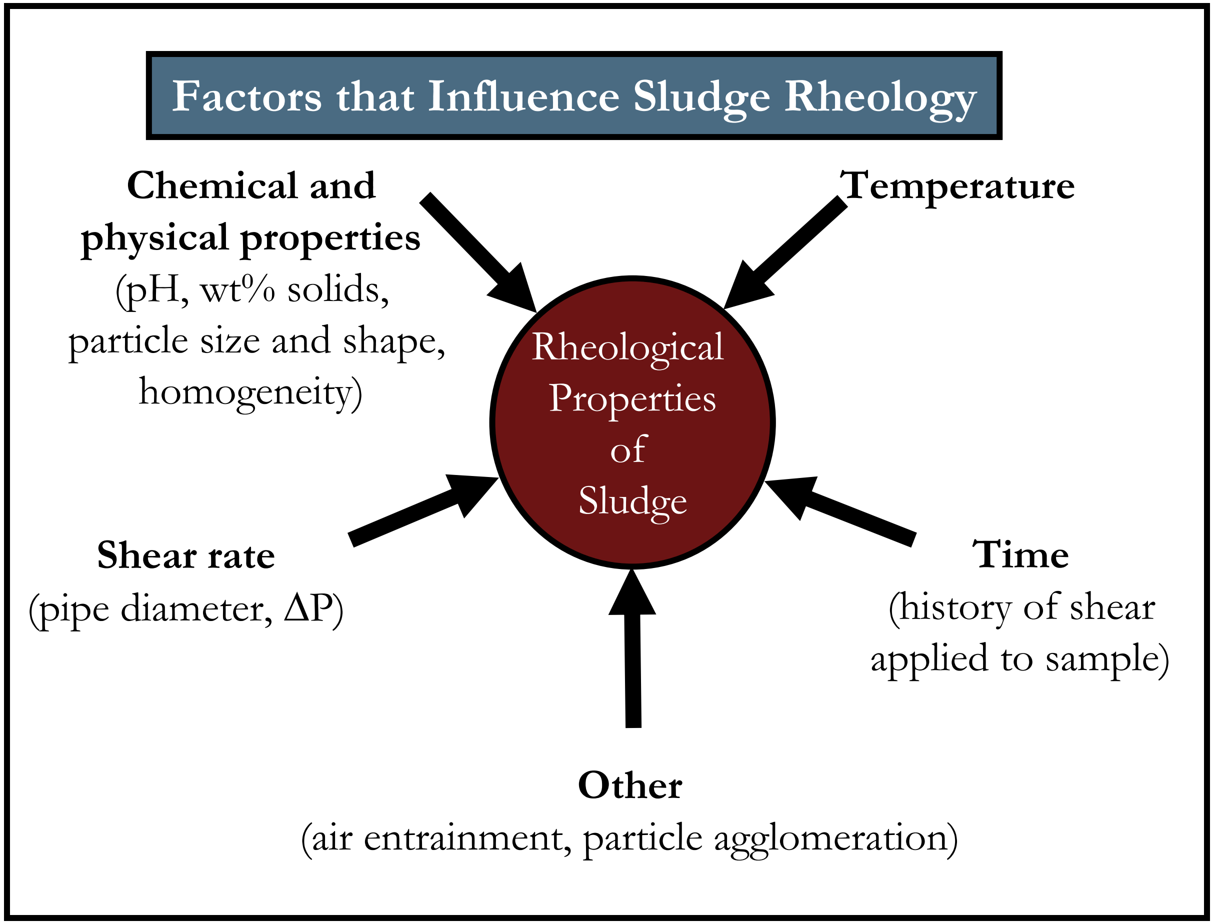




- Calculated Wall Shear Stress Patterns agree with observed wear patterns.
- The relative magnitude of shear stress compare well with depth of erosion.

Si Y. Lee, Richard A. Dimenna, John R. Neuville, Glenn A. Taylor, EROSION MODELING ANALYSIS FOR DWPF SME TANK; WSRC-TR-2003-00534

Summary



Tools Available

SRNL analytical
CFD modeling
Rheology modifiers
Frit bead testing